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FROM THE PONDERABLE TO THE IMPONDERABLE[1]

By Professor OTTO HAHN

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CHEMISTRY has for its purpose the study of the composition of our material world. Its first task is to determine the simple basic substances—the chemical elements—out of which all other substances are made, and artificially to produce new kinds of substances from these same elements. After its problem had been thus recognized and defined, thanks chiefly to Robert Boyle, chemistry could be spoken of as a "science," striving, in contrast to the direction of earlier efforts, towards an ideal objective through unprejudiced researches. The prerequisite for these researches was the recognition of the fact that the weight of a chemical compound is equal to the sum of the weights of its constituents. We owe to the French chemist Lavoisier the recognition of the full significance and the ingenious application of this law. We have him to thank for introducing the well-known balance as a reliable guide in chemical work, whereby Lavoisier became the true founder of modern chemistry whose victorious march began in the nineteenth century and has continued at a steadily increasing tempo.

To be sure, Lavoisier's immortal services were poorly rewarded by his contemporaries; in 1794, during the confusion of the French Revolution, the Revolutionary Tribunal sent him to the guillotine.

My topic is "From the Ponderable to the Imponderable" in chemistry, in physics, and I might also add, in biology. How far can we extend the limits of our qualitative and quantitative tests of chemical compounds? Are there methods of investigation that are reliable at and beyond the present limits of our balances? What are the lower limits?

As a science develops, its methods are improved and its aids become more and more refined. The

[1] Introductory public lecture.

quantitative analytical balance of the time of Lavoisier certainly differed very considerably from the balances used in chemical laboratories to-day by every young student of chemistry. But even along this line development has not yet ceased. As it becomes possible to work with smaller and still smaller quantities of material, to that same degree we refine our analytical methods and the delicacy of our tests. The methods of "microchemistry" have now been added to those of ordinary or "macro" chemistry.

The usual modern analytical balance permits a mass of a few hundred grams to be weighed accurately to within one ten-thousandth of a gram. About thirty years ago Nernst devised the micro-balance that bears his name, which weighs a few milligrams of material to within a few millionths of a gram. This device was followed by the Kuhlmann balance—now widely used in microchemistry—which weighs amounts of even twenty grams to within a millionth of a gram. This was a tremendous advance, but the end was not yet; special methods enable us to weigh smaller amounts of material with very much greater accuracy.

In such direct weighings the material is always still available in masses that are fractions of grams; by other methods it is possible to make qualitative and quantitative determinations of chemical compounds in masses whose lower limit is finally determined by their visibility under the microscope. It may be stated as a quite general truth that whenever, for any reason, it seems necessary positively to determine minute amounts of material, there will be found means and ways for doing so. This statement may be explained by a few examples.

When the world war was over and the victors imposed upon Germany the task of finding enormous sums for "reparations," Fritz Haber proposed to himself the most interesting scheme of extracting gold from the inexhaustible reservoir of the oceans. Previous determinations by other investigators had placed the gold content of sea water at five to ten milligrams of gold per metric ton (one thousand kilograms) of water. The gold ores of South Africa contain about one thousand times more gold per ton than does sea water, but the greater ease of working water, as compared with rigid rock, made the task seem very promising. If it succeeded it would open up an inexhaustible source of gold, for Arrhenius had estimated that, with a richness of six milligrams of gold per ton of water, the total content of all the seas amounted to eight billions of tons of gold.

The plan itself—to secure gold in this way—did not succeed and could not succeed. Instead of the assumed gold-content of five to ten milligrams per ton, Haber's numerous experiments showed only about one thousandth as much. But they accomplished a great advance in the analytical methods for separating out minute amounts of material. Microscopic measurement of the tiny gold spherules obtained from the precipitation enables one to determine with certainty one ten-millionth of a gram or less. This determination of microscopic traces of gold was successfully employed in explaining and combating experiments that in their day caused great excitement because they seemed to indicate the supposed transmutation of mercury into gold.

Mercury furnishes another illustration in this connection. While Alfred Stock was working in Berlin he became a victim of the injurious effects of small amounts of mercury. He combined his great educational campaign regarding the deleterious nature of the cheaper amalgam dental fillings, with the development of a demonstration of the presence of very small amounts of mercury in the saliva, in urine, and in exhaled air. As a result it is possible to demonstrate the presence of a hundred millionth of a gram of mercury in the form of tiny crystals of mercury iodide, so minute as to be barely visible under the microscope.

Many other chemical elements and compounds might be cited, that have been identified in such amounts by weight as would never have been possible without the aid of the increasingly important methods of microchemistry.

It will now be asked whether there is really any good reason for such extraordinary refinement in our experimental aids for recognizing and quantitatively determining such small amounts. It is by no means a matter of indifference whether we can prove the presence somewhere of a minute amount of a metal or of a chemical compound as an impurity of other metals or compounds. Modern research has demonstrated the great influence exerted upon the hardness, ductility and durability of metals by very small additions of other substances to them. Again, in all the life processes of plants as well as of animals, substances present in minutest amounts often play a much greater rôle than do those substances occurring in easily determinable quantities. Mere mention of enzymes, hormones, vitamins, is sufficient to point out such substances to you; we shall return later to their consideration.

In order to understand how it is that the smallest amount of a substance can so often produce such great effects, it must be remembered that even the smallest of the weights mentioned above, *viz.*, one one-hundred-millionth of a gram consists nevertheless of a very large number of those minute particles that we call atoms or molecules.

As to the number of molecules obtained in a given weight of a chemical compound, this can be accurately determined if we know its molecular weight, as it is called; and the latter can almost always be readily

ascertained. The atomic or molecular weight in grams of a substance contains the inconceivably large number of 6×10^{23} atoms or molecules. Some interesting computations by the English physicist Aston[2] enable one to form some conception of their quantity. Suppose we have an absolutely evacuated incandescent lamp bulb of the usual size, and make an opening into it so fine that one million molecules of air enter in one second. Then one hundred million years must elapse before the bulb will fill with air to atmospheric pressure.

Again, suppose that in some way each of the molecules in the two hundred grams of water contained in an ordinary glass of water could be made visible, could be labeled or tagged. If this glassful of water were then poured into the ocean at any point—Australia, the Gulf of Mexico, some Russian river—then after a very long time the two hundred grams would be uniformly distributed throughout the oceans of the globe. Now if a glass of water were dipped up at random from the ocean at any point, whether from the surface or from a depth of six thousand meters, there would be found more than two thousand of those tagged molecules in this glass of sea water.

Finally, take an example from my own particular field of radioactivity. Through atomic disintegration the element uranium gradually changes into the element lead, in fact during every second ten thousand atoms are converted per gram of uranium. But seventy-one million years must elapse before this single gram of uranium has formed one hundredth of a gram of lead.

Returning to the tiny amounts of gold and of mercury mentioned above, it is easily computed that there must be millions of millions of atoms or of molecules in the microscopic particle of gold or of the mercury salt referred to. It is justifiable to inquire whether there are methods by which one can recognize amounts even smaller than those considered above—quantities lying beyond the limits of direct weighing or of direct vision. This question is answerable distinctly in the affirmative, and we shall now consider a series of such methods.

First in interest among these methods is that of spectrum analysis, devised by Bunsen and Kirchhoff, which reveals the chemical composition of a substance by the spectral lines that its vapor emits under appropriate excitation. You all know that this method has revealed to us the chemical composition of the heavenly bodies, and proved that they consist of precisely the same elements as does our earth. Bunsen and Kirchhoff sought to determine the smallest amount by weight that was recognizable by their method, and they found that in the case of sodium as little as 3×10^{-10} gram could be detected spectroscopically. To be sure, the practical execution of their experiments required considerably larger amounts (practical *vs* theoretical sensitivity). Many gaseous elements have a much higher spectroscopic sensitivity than do the solid metals like sodium. Paneth's researches in particular should be mentioned in this connection. He has been able to identify the noble gas helium in amounts as small as 2×10^{-14} gram, and to make quantitative determinations of as little as 2×10^{-11} gram, employing Otto Stern's later refinements of Pirani's method. Here again is illustrated the fact—so gratifying for the progress of science—that when a new task is set the means and methods for accomplishing it are also often discovered. Paneth and his coworkers employed his refined spectroscopic method in their quantitative determinations of the minute helium content of a large number of iron meteorites, and thereby determined the age of these heavenly bodies. Paneth came to the remarkable conclusion that meteorites probably originated within our solar system and not—as was previously assumed—from fixed stars outside that system.

Spectrum analysis has recently found an extraordinarily fruitful field in applied qualitative and quantitative chemical analysis. The demonstration by spectrum analysis of the "ultimate lines" of the elements now enters into an ideal contest with former micro-analytical methods, "spot" analysis and potentiometric titration in the determination of the least traces of impurities in metals, forensic preparations, and other substances (Gerlach and his coworkers).

Of late years x-ray spectroscopy also has developed as a powerful tool for chemical research, making possible the discovery of new elements at their lowest concentration, and the determination of impurities in metals that would certainly have escaped detection by ordinary chemical analysis.

To consider this broad and fruitful field of study in more detail would take us far beyond the limits of a one-hour address. A single method of optical identification may briefly be considered, however, since it served in its day to solve a problem that was of interest to the non-technical world. Organic chemistry knows of dyes whose aqueous solutions have very intense coloring powers; infinitely minute amounts of these dyes can be detected even at extraordinary degrees of dilution. Among these coloring substances is fluorescein, discovered by A. von Baeyer. At the suggestion of von Baeyer this property of fluorescein was employed in 1877 to determine a supposed subterranean connection between the Danube and the Rhine rivers. A solution of ten kilograms of fluorescein was sunk in the Danube near

[2] F. W. Aston, *Nature*, 110: 702, 1922.

its head springs. After an interval of about sixty hours the characteristic fluorescence of the dye appeared in a little river which empties into Lake Constance and thence into the Rhine, but has no visible connection with the Danube. The coloration lasted for about thirty-six hours. The supposed connection between the two rivers has been proven experimentally.

Turning from these optical methods that impress the vision, to methods working through other senses, our attention is held above all by such substances as appeal to the sense of smell. Here it is found that through this sense one can recognize substances present in quantities that are far below the limits of the chemical balance.

As early as 1887 a classical investigation in this field was carried out jointly by Emil Fischer and E. Penzoldt. Up to that time the sense of smell was thought to be most sensitive toward the odor of attar of roses. The presence of an unbelievably small trace of this perfume can be detected in this manner. But these two investigators found that even smaller amounts of a derivative of hydrogen sulfide, mercaptan, could readily be recognized through its powerful and highly disgusting odor. When the air of the room contained by volume one part of mercaptan in three hundred million parts of air, the stench was so penetrating that "the odor passed off only gradually even after opening four windows, two doors, and setting up a strong draft." Fischer and Penzoldt found that as minute an amount as one part in fifty thousand million of air could thus be recognized. On the assumption that about fifty cubic centimeters of air must flow past the olfactory nerves of the nasal passages to make an odor noticeable, the amount of mercaptan that can be recognized by its stench is one four hundred and sixty thousand millionth of a gram, an absolutely unweighable quantity.

In the course of time the limits of detection by smell were determined for many other agreeable and evil smelling substances, and a great many of them were found to be as potent as is mercaptan. Among the fragrant substances are ionon (the essence of the violet) and vanillin (the fragrant substance in vanilla). Among the evil-smelling bodies may be mentioned butyric acid, whence comes the stench of rancid butter. The enjoyment of sweet butter is spoiled for us by absolutely unweighable amounts of that compound.

A computation of the number of molecules of these substances detectable by smell always shows that many million molecules of the substance are involved per cubic centimeter of air. There is no great wonder, then, that certain animals seem to be able to recognize a very much smaller amount of disagreeable and of fragrant substances. The dog's and the insect's sense of smell are good examples, and particularly that of butterflies—whose scenting powers actually border on the marvelous. The Swiss naturalists Fabre and Forel report the following experiment: The caterpillar of a butterfly was raised in the city of Zurich, spun its cocoon and emerged the following spring as a female butterfly. This female was imprisoned in a room with windows open, but within two days more than one hundred males of the same species had gathered in the room; they had traveled a number of kilometers from the forests in the environs of Zurich. Such statements might be relegated to the realm of fable had they not been adequately confirmed.

We turn now to another field. The preceding methods for identifying minute amounts of material have in common the feature that the substance is always recognized by some one of its specific characters. But there is an almost boundless number of phenomena in which the presence or absence of minute amounts of substances is detected, not directly, but through the effects they produce. Among these the most important are the effects upon life processes.

Thus, many metals and chemical compounds exert a poisoning influence on the lower organisms. Disinfection and antiseptic methods are based upon this fact. A couple of pictures showed how small the amount may be and yet produce an evident effect.

The first slide showed a group of houses in a small town of southern Germany. These houses are roofed with a flaggy limestone from the Jura, and in the course of time the growth of a great variety of mosses and lichens has given these slabs a beautiful dark patina. The picture showed that some of these house roofs are crossed by a pair of parallel white streaks. There the growth of moss and lichens is absent. The reason for this is that two naked copper wires pass above these houses, the rain dissolves traces of copper, the extremely dilute copper solution drips on the roofs, and in these areas the plant growth is interrupted.

This poisoning effect upon the lower organisms of minute amounts of metal was clearly shown in the next slide. A nutrient agar-agar preparation was inoculated with a culture of *Staphylococcus,* and a silver coin was laid upon it.[3] The dish was kept in the dark and at a low temperature for several days. Under these conditions the bacteria do not multiply, but traces of the silver can nevertheless diffuse through the nutrient. Later the dish was placed in a warm incubator, whereupon a luxuriant growth of bacteria developed. Around the coin, however, there was a space free from bacteria, where the dissolved metal had prevented their growth. In such a case it certainly would be very difficult to prove the presence

[3] H. Beehold, *Kolloid-Z.*, 25: 158, 1919.

of silver by one of the usual chemical methods, for the silver content per cubic centimeter of nutrient solution could have been only a few hundred-millionths of a gram.

Recently the katadyne process had made extensive use of this so-called "oligodynamic" effect. The very large number of papers and patents relating to the sterilization of water, milk, and other substances, testify to the steadily increasing significance of this process. It is interesting to find that the ancient Egyptians employed this disinfecting action of minute amounts of dissolved metal. Open wounds healed better and more rapidly if they were covered with silver plates. The traces of dissolved silver prevented infection. Bone fractures repaired with silver wire show a greatly reduced tendency to infection.

In the cases here mentioned these infinitesimal amounts of material acted as poisons toward low forms of life. Much more important for all life-processes are those cases where the presence of a very small amount of substance is essential for life-processes, where lack of it produces deficiency phenomena and can mean illness and death.

This brings us to the supremely important field of the enzymes, vitamins and hormones. The catalytic enzyme or ferment reactions that are so determinative of organic phenomena find their inorganic, model-like counterpart in the catalytic decomposition of hydrogen peroxide into water and oxygen by minute traces of the noble metals present in the most finely divided state. Many years ago Bredig found that three millionths of a gram of colloidal platinum per liter of water produced a marked acceleration in the decomposition of hydrogen peroxide. Conversely, the slightest trace of "catalytic poisons" suffices to hinder this action by platinum; scarcely more than one millionth of a gram of hydrocyanic acid per liter of water was found to produce such a "poisoning."

The living cell shows corresponding catalytic reactions. The respiratory ferment, which is indispensable for cell growth, and which has been studied in detail by Otto Warburg, contains minute traces of iron—the so-called "enzyme iron." Only very delicate qualitative reactions can prove the presence of this iron. Nevertheless, the cell's life is extinguished if the iron is removed or its action is chemically prevented. As in the catalysis of hydrogen peroxide by platinum, very minute amounts of hydrocyanic acid put an end to the catalytic action, "poison" the respiratory ferment, and the respiratory activity ceases.

Less understood, as yet, than these enzyme reactions is the mechanism of the effects observed in connection with the "hormones." A few illustrations may be given. The human thyroid gland secretes thyroxine, an organic compound containing iodine, whose absence can induce severe metabolic diseases; in the lower animals a hereditary lack of this compound causes extraordinary effects. An American species of salamander, the Axolotl, often fails to complete its metamorphosis—particularly when in captivity—from the aquatic, gill-breathing larval stage to the fully developed terrestrial, lung-breathing animal. A single abdominal injection of a hundred thousandth of a gram of thyroxine suffices to produce promptly and positively the otherwise suspended metamorphosis.

A tadpole that develops very slowly if at all in water wholly freed of iodine, accomplishes its metamorphosis in a thyroxine solution of one part thyroxine to five thousand million parts water, and more rapidly than it would in an otherwise normal environment.

In these cases minute amounts of organically combined iodine have released vitally important functions, and in other cases minute amounts of other chemical elements have produced corresponding phenomena. During the past year Schmucker[4] in Göttingen has strikingly demonstrated the extraordinary and specific physiological activity of a minimum concentration of boric acid. He experimented with the pollen grains of tropical water lilies whose natural nutrient liquid contains small amounts of boric acid. If this boric acid is removed development ceases; if it is added in amounts of a hundred thousandth to a millionth, normal development is resumed. In this case the boric acid may actually be described as an "inorganic hormone."

Special interest attaches to the growth-producing substance "auxin" recently investigated by the Dutch botanist Went,[5] and prepared in the pure state by the German chemist Kögl.[6] The growth of plants requires extremely slight amounts of this hormone-like compound, in addition to the other materials belonging to plant structures. When an oat-sprout is "topped" to remove the tip, the growth of the sprout is stopped. If a trace of the "auxin" preparation—which can be extracted from the cut-off tip—is applied to the truncated end, growth is revived. An application of the "auxin" to one side of the sprout's end revives the growth on that side only; the sprout therefore curves toward the opposite side. The unit amount of "auxin," that which suffices to cause a curvature of about 10°, has been called the "avena unit." Kögl has now successfully prepared the pure crystallized growth-producing substance "auxin," and it has been found that the growth-unit just defined is produced by the fifty-millionth part of a milligram, that is, 2×10^{-11} gram of "auxin." In the first attempts to secure this very interesting substance maize

[4] Schmucker, *Naturwissenschaften*, 20: 839, 1932.
[5] Went, *Naturwissenschaften*, 20: 596, 1932.
[6] Kögl, *Chem. Weekblad*, 29: 21, 1932.

and oat sprouts were used; but even one hundred thousand maize tips contain only very small amounts of "auxin." Its best source was finally found to be human urine, which is a source of many highly important physiological substances. It has been found that every human being, regardless of age or sex, secretes on the average two milligrams of auxin daily.

The foregoing expositions have shown that there are many ways, some direct and some indirect, for proving the presence of substances and determining their exact amounts when the latter are beyond the scope of the chemical balance. At the same time, however, it has been found that even the least of the amounts we have considered consists of a very large number of molecules. Is there, then, no bridge leading from these relatively gross quantities to the individual atoms?

In the closing years of the last century there were discovered the radioactive substances, and these actually do furnish the key that has, at one turn, opened the gate to this field formerly regarded as closed to exploration. The final section of this lecture will therefore be devoted to a consideration of these radioactive substances.

Radioactive elements are those which are subject to spontaneous intra-atomic disintegration. The discharge of small fragments of atoms—the so-called "radioactive rays"—gives rise to new elements possessing new chemical and physical properties. The radiant particles emitted during the disintegration are characterized by an enormous initial velocity and it is because of their high velocity that the particles, in spite of their merely atomic magnitude, reveal their presence in the most varying ways through the effects they produce. These effects of the radiation constitute the fundamental difference between the long-known chemical and the new radioactive methods of investigation. In the former case ordinary stable atoms are used for investigation, and all that has been said shows that many millions of atoms or of molecules are required for such work. In the case of the radioactive substances one measures at the instant of emission the rays coming from the disintegrating atoms. Thus it is not the absolute number of atoms present, but the number of atoms disintegrating during the period of measurement that is of importance. By studying this radiation-intensity it is possible to investigate a whole series of different radioactive atoms (chemical elements) in masses that are far below the limits of chemical identification. By means of their radiations invisible and unweighable masses can be recognized as present, and they can also be accurately analyzed and determined quantitatively. The broad field of applied radiochemistry employs these properties of radioactive substances to study the behavior of imponderable amounts in the presence or the absence of inactive accompanying substances; it puts into our hands the means for attacking and solving chemical and physico-chemical problems unanswerable by other methods.

There is not time to discuss this matter now in any detail and a few brief references must suffice. In connection with spectrum analysis it was mentioned that optical methods enabled us to demonstrate the presence of traces of impurities in metals and chemical compounds. Radioactive methods enable us to go yet further and to study the laws according to which unweighable amounts of foreign materials are taken up by their carriers.

The next photograph showed two crystals of different salts. One was a natural crystal, gypsum, which after irradiation had the striking property of phosphorescence along certain of its crystalline surfaces.[7] There is hardly any doubt but that this selective phosphorescence was due to minute amounts of impurities deposited regularly on the crystal as it was growing. The probable correctness of this explanation was shown by the second crystal, rubidium sulphate, which we made artificially and which contained less than one billionth of a gram of a radioactive substance (lead). This crystal was placed in the dark upon a photographic plate, and the latter was developed after a short exposure. The picture showed plainly that these absolutely imponderable amounts of radioactive material here also were deposited in a regular manner. The remarkable character of this distribution could not possibly be determined by other than radioactive methods, because the infinitesimal amounts involved in these inclusions can not be detected by analytical chemical methods.

When the radioactive substance is not embedded in a crystal, as in the case just considered, but is adsorbed by minute particles in a liquid or a gas, it is possible to determine directly the nature of the radioactive element emitting the rays, from their effects on a photographic plate. The next illustration showed how this is possible.[8]

One could notice that there were a number of dark circular figures of various diameters; the diameters of these circles are quite definitely characteristic of certain radioactive substances. Were other substances of this kind present, the circles or zones would have a different radius. This makes it possible to identify a chemical element in this way when perhaps a thousand or less atoms are present, and there is nothing to prevent the detection of a still smaller number of atoms.

These circles, called "radioactive zones," produced here artificially upon the photographic plate, occur naturally in many minerals and are of prime significance in problems on the history of our earth. In

[7] *Handbuch der Experimentalphysik*, Band XXIII, 2 (Tomaschek).

[8] See Mlle. C. Chamié, *Comptes rendus*, 1929–1931.

the pleochroic halos, so-called, one has to do with very small, circular images; they are found in particularly beautiful development in a fluorite from southern Germany. The colored medium in this case is the decidedly less sensitive rock in place of the highly sensitive photographic plate. Our next slide showed photographs of such zones or halos.[9] They appear as a large number of concentric circles, each circle corresponding to a particular one of such radioactive decomposition-products as are found in uranium or thorium minerals. The interruption of the circular area by brighter annular bands results because the rays are most effective at the respective limits of their so-called "range." Minute traces of radioactive minerals are embedded in the inactive fluorite, and have sent their rays into the surrounding mineral which they have colored.

Experimental determinations of the number of rays necessary to produce these zones and the microscopical measurement of the volume of the radioactive dust particles that caused the halo, enabled Rutherford and Joly to figure out that in many cases several hundreds of millions of years were required to produce such halos. This demonstrates the tremendous age of the solid crust of the earth. The study of these pleochroic halos reveals the almost overwhelming fact that it is possible in this way to demonstrate atomic transformations in which, every few years, one single atom breaks down with the emission of a radiant particle. Compare with this the fact that in one milligram of radium, seventeen million atoms disintegrate every second, and yet thousands of years must elapse before this minute mass of radium has been completely transformed.

Radioactive phenomena, in fact, now offer us the possibility of determining and studying the behavior of substances consisting of only single atoms. The so-called "Wilson cloud-chamber" carries out such work in an especially intensive manner, and in conclusion some slides were presented demonstrating the principle of this method and pointing out what it can accomplish.

When the alpha rays of radioactive substances traverse the air it is well known that they produce positively or negatively charged air particles—the so-called "ions." If this air is saturated with water vapor and then rapidly cooled, the cooling causes the vapor to condense in cloud droplets where these ions are present. Under suitable illumination, the mist in the air chamber is plainly seen to be divided into sharp lines, and these lines correspond to the paths of the ions from the alpha rays. The length of the path represents the range of the alpha rays in air.

Each of the many straight lines corresponds to a radiant particle and therefore to a disintegrated atom. In a case illustrated, the disintegration of two different substances was involved, therefore there were noted two different groups of rays, one having a greater and the other a lesser field of action. Clearly a much smaller number of rays than that shown can be recognized in this way.

The next figure showed something else. In addition to the brush of numerous normal alpha rays, there appeared in one place a longer and much thinner ray.[10] This was a hydrogen ray that had been set in rapid motion by an alpha ray, a rather unusual phenomenon. These fog-tracks aid in the photographic recording of such rare atomic processes. The modern terms atomic disintegration, atomic structure, neutrons, indicate how extraordinarily fruitful for the modern physics of the atom is this method of photographing fog-tracks.

The Wilson photographs clearly demonstrate our ability to detect extremely minute amounts of material, but an even more striking illustration of the sensitivity of this method was furnished by an occurrence in the speaker's laboratory in the Kaiser Wilhelm Institute in Dahlem.

While Wilson photographs were being made in Professor Lise Meitner's room in the physics section of the institute, one of the speaker's collaborators opened, in the distant chemistry section, a vial containing a solution of a few milligrams of radium. A fraction of the radium emanation, not more than about one one-hundred-millionth of a gram, escaped into the laboratory. Thence a smaller fraction escaped into the corridor, and thus an infinitesimally small quantity entered the room where the Wilson photographs were being made. The result was recorded on the photograph shown in the last view. One could see a multitude of Wilson-paths running crisscross through the photographing chamber; these had been made by emanation atoms that had entered the Wilson-chamber, and, at the moment of exposure, had been disintegrated by ray emission. These minute traces of emanation "infected" the apparatus, and perfect records could not be made again until the last trace of emanation had been removed from the chamber, or had disintegrated.

We may esteem ourselves fortunate that the detection of non-radioactive substances is less sensitive than those that have been described. If we could see how many nuclei of dirt, dust, and disease are contained in the air we constantly inhale, we might be terrified and hardly dare to breath. Nature in her wisdom has arranged matters so that in the course from the ponderable to the imponderable the limits of visibility coincide approximately with the limits of weighability. Let us be thankful that it does not reach down to the individual atoms!

[9] Gudden, *Z. Physik*, 26, 110, 1924.

[10] For these Wilson-photographs the speaker was indebted to Professor Lise Meitner.

SCIENTIFIC EVENTS

HUMAN REMAINS DISCOVERED BY THE BRITISH EAST AFRICAN EXPEDITION

A CONFERENCE was called by the Royal Anthropological Institute on March 18 and 19 to discuss the early human remains recently discovered by the East African Expedition of Dr. L. S. B. Leakey, and to examine the material which is now assembled in Cambridge. *Nature* reports that after hearing Dr. Leakey's exposition of his discoveries, and a general discussion of questions arising therefrom, the conference appointed committees to report, respectively, on the geological, paleontological, anatomical and archeological evidence.

The committee on paleontology reported that Kanam East and Kanam West exhibit differences only in the relative numbers of the fossils of different groups. With the human jaw at Kanam West were found close relatives of the two types of rhinoceros still living in the region, a small hippopotamus, a pig, an antelope, fragments of mastodon, two teeth of a very large deinotherium and remains of *Trionyx*. In Kanam East the collection consists chiefly of mastodon with a primitive elephant, deinotherium, and a few specimens of hippopotamus, rhinoceros, horse and a young monkey.

The fossils from Kanjera have a later aspect. One elephant has dental plates as deep as those of *E. antiquus*, and all the remains of elephant are of Asiatic or European type. At least two antelopes, *Hylæochœrus*, *Phacochœrus*, and a large pig distinct from that of Kanam West, have a very modern appearance. A baboon is remarkable for its comparatively short face. One equine upper molar approaches *Hipparion*, if it does not actually belong to that genus. Typical *Equus* also occurs. Fragments of mastodon, rhinoceros, a giraffoid, hippopotamus and a carnivore have also been found.

The committee thinks that the Kanam deposit should be referred to the Lower Pleistocene, in which the deinotherium and mastodon are survivals from the Upper Pliocene. It also thinks that the Kanjera fauna can not be later than the Middle Pleistocene.

The conference, according to *Nature*, after detailed discussion and after receiving supplementary information furnished by Dr. Leakey and Mr. McInnes as to the circumstances of their discoveries, accepted the reports; congratulated Dr. Leakey on the exceptional significance of his discoveries, and expressed the hope that he may be enabled to undertake further researches, seeing that there is no field of archeological inquiry which offers greater prospects for the future. It especially urged the early organization of another expedition. The following were present and concurred in the above conclusions: Sir Arthur Smith Woodward (*chairman*), A. L. Armstrong, H. Balfour, Miss D. M. A. Bate, P. G. H. Boswell, M. C. Burkitt, V. G. Childe, L. C. G. Clarke, W. L. H. Duckworth, H. J. Fleure, C. Forster Cooper, V. E. Fuchs, A. C. Haddon, A. T. Hopwood, O. T. Jones, Sir Albert Kitson, L. S. B. Leakey, D. McInnes, E. H. Minns, J. Reid Moir, J. L. Myres, T. G. Mollison, F. Oswald, K. S. Sandford, R. A. Smith, W. J. Sollas, J. D. Solomon, Miss M. L. Tildesley and D. M. S. Watson.

THE MORRIS ARBORETUM OF THE UNIVERSITY OF PENNSYLVANIA

THE Morris Arboretum of the University of Pennsylvania will share in a collection of more than 30,000 mounted botanical specimens from eastern Asia as a result of its participation in a botanical expedition which has been at work there under the direction of Dr. Joseph F. Rock, of the U. S. Department of Agriculture.

According to Dr. Rodney H. True, professor of botany at the university and director of the arboretum, in addition, the seed of several hundred varieties of Oriental plants, many of which offer possibilities of reproduction in this country, will also come to the arboretum from the Rock expedition.

Of the collection made by Dr. Rock, who has been agricultural explorer in the office of foreign plant introduction of the Department of Agriculture since 1920, only about one third has thus far been classified.

These classified specimens, which include more than five hundred rhododendrons, one hundred and fifty primulas, and many varieties of lilies, magnolias and the poppy-like mecanopsis, were found near the headwaters of the Irrawaddy River, in the province of Tsurong west of the Kaaker range, along the upper Salween River, and in other districts chiefly in southeastern Tibet. The remaining two thirds of the specimens, as yet unclassified, have been collected in a wide area which includes in general the region between the Yangtze and Mekong Rivers and a section north of Muli. This latter section hitherto had been untouched in botanical explorations.

In addition to the Morris Arboretum, the shareholders in Dr. Rock's expedition include the Arnold Arboretum, of Boston; the New York Botanical Garden; the Edinburgh Botanical Garden; H. D. MacLaren, of Bodnant, Wales; the Morton Arboretum, Lisle, Illinois, and the University of California.

The material collected is being sent to the University of California where it is being assembled and

classified for future distribution to all the shareholders in the expedition.

According to Dr. True, the participation of the Morris Arboretum in the Rock expedition marks the first step in the arboretum's program for the collection of rare botanical specimens from all parts of the world. Although the arboretum already has a wide representation of Oriental plants, its herbarium will be greatly enriched by the mounted specimens from Tibet. It is expected that the seeds from the Rock expedition will enable the arboretum to grow many varieties of Oriental plants.

DEDICATION OF THE GEORGE EASTMAN RESEARCH LABORATORIES OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THE George Eastman Research Laboratories of the Massachusetts Institute of Technology will be dedicated on Monday, May 1.

The new building, which takes its place in the main educational group, will be devoted to advanced training and research in physics and chemistry, and many former students and members of the faculty in these fields will return for the dedication. It was built from a fund originally provided by the late George Eastman for new buildings, and was completed last autumn. The laboratory offers the most advanced facilities for fundamental study and teaching.

The ceremonies will open with a meeting in the large lecture room of the laboratories in the morning, when the guests and official delegates will be welcomed in an address by President Karl T. Compton. Dr. Harry M. Goodwin, dean of the Graduate School, will speak on "The Graduate School," and Professor Frederick G. Keyes, head of the department of chemistry, will discuss "Chemistry at the Massachusetts Institute of Technology," tracing the development of advances in this field at the institute since its beginning. "Physics at the Massachusetts Institute of Technology" will be the subject of an address by Professor John C. Slater, head of the department of physics. The meeting will be followed by an inspection of the laboratories and special exhibits.

After a buffet luncheon in the Walker Memorial Building, the delegates will attend a meeting at which Dr. Arthur H. Compton, of the University of Chicago, will contribute a paper entitled "Cosmic Rays," and Professor Charles A. Kraus, of Brown University, will speak on "Thirty Years of Physical Chemistry."

After the meeting, the inspection of laboratories and exhibits will be resumed, to be followed by a tea in the Forris Jewett Moore Room late in the afternoon. At 6:30 in the evening the delegates will attend a dinner in Walker Memorial. The ceremonies will close with a reception by President Compton and the staff of the George Eastman Research Laboratories.

As a preliminary to the dedication of the new building, the Northeastern Section of the American Chemical Society, with members of various other New England sections as its guests, will meet in the new building on Saturday afternoon and evening, April 29. Dr. Gilbert N. Lewis, dean of the College of Chemistry at the University of California, a former member of the faculty, will make an address at the afternoon meeting on "The Preparation and Properties of Pure Hydrogen Isotope." At the dinner in the evening, Professor Ernest H. Huntress, of the department of chemistry, will perform a number of unusual experiments in chemistry.

THE MINNESOTA ACADEMY OF SCIENCE

LAST October there were held in the Twin Cities several meetings with a view to organizing a Minnesota Academy of Science. Formal organization was finally completed at a meeting held on November 18. The officers elected and appointed were:

President, Wm. A. Riley, University of Minnesota, St. Paul.
Vice-president, H. E. Stork, Carleton College, Northfield.
Secretary-Treasurer, D. E. Minnich, University of Minnesota.
Councilors, George Friedrichs, State Teachers College, St. Cloud; Richard U. Jones, Macalester College, St. Paul; Reverend Wendel Luetmer, St. John's University, Collegeville; E. T. Tufte, St. Olaf College, Northfield.

On April 15, the first annual meeting of the academy was held in the Zoology Building at the University of Minnesota. At a morning and an afternoon session eighteen papers were read. The papers covered a wide variety of fields, including biology, chemistry, geology and astronomy. The noonday luncheon was the occasion of two addresses: one by Dr. L. M. Gould, of Carleton College, on "Antarctic Glaciation," and one by Dr. A. E. Jenks, University of Minnesota, on "Anthropologic Problems of Special Interest in Minnesota." Forty-nine new active members and five new associate members were elected to the academy.

The following officers were elected for the coming year:

President, H. E. Stork, Carleton College, Northfield.
Vice-president, T. B. Magath, Mayo Clinic, Rochester, Minnesota.
Secretary-Treasurer, H. K. Wilson, University of Minnesota, St. Paul.
Councilors, George Friedrichs, State Teachers College, St. Cloud; Richard U. Jones, Macalester College, St.

Paul; Wendel Luetmer, St. John's University, Collegeville; E. T. Tufte, St. Olaf College, Northfield.

THE SALT LAKE CITY MEETING OF THE PACIFIC DIVISION OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

BY invitation of the University of Utah, the Pacific Division of the American Association for the Advancement of Science and associated societies will hold their seventeenth annual meeting at Salt Lake City. Unusually attractive rates have been offered by the railways for members proposing to attend the meeting.

The sessions will commence on Monday, June 12. In the afternoon a series of reviews pertaining to the progress of scientific research will be presented. The subjects and authors are: Meteorology, H. H. Kimball, Harvard University; Geology and Seismology, Eliot Blackwelder, Stanford University; Astronomy and Astrophysics, R. G. Aitken, Lick Observatory; Chemistry in Relation to Medicine, Chauncey D. Leake, University of California.

Problems of major interest and the most noteworthy accomplishments in each of these fields will receive attention.

The morning of Tuesday, June 13, is to be devoted to a symposium on "Scientific Problems of the Great Salt Lake." The subjects selected for consideration will be presented as follows:

"The Ancestry of Great Salt Lake," F. J. Pack, professor of geology, University of Utah.

"Climatological and Hydrological Problems," T. C. Adams, associate professor of civil engineering, University of Utah.

"Chemical Deposits and Problems," T. B. Brighton, professor of metallurgy, University of Utah.

"Animal Life and Relations," R. V. Chamberlin, professor of zoology, University of Utah.

"Observations on Artemia," E. G. Martin, professor of physiology, Stanford University.

"Plant Life and Relations," W. P. Cottam, professor of botany, University of Utah.

The general addresses to be delivered before the division at large are scheduled for the evenings of June 12, 13 and 14. The first will be by Dr. W. F. Durand, president of the Pacific Division, on "The Development of our Knowledge of the Laws of Fluid Mechanics"; that of Tuesday evening will be given by Dr. H. H. Kimball, of the Blue Hill Observatory, Harvard University, on "Meteorology—Ancient and Modern; its Development and Applications," and that of Wednesday evening, June 14, by Professor Bailey Willis on "Earthquake Habits of Many Lands."

June 15 will be the closing date for all the organizations participating in the meeting, except the American Physical Society and the Astronomical Society of the Pacific, whose programs extend over June 16.

Members of associated societies are reminded that the titles of papers to be presented at the meeting must be submitted as soon as possible for inclusion in the program.

SCIENTIFIC NOTES AND NEWS

WILLIAM HENRY HOLMES, chief of the Bureau of American Ethnology from 1902 to 1910, who retired last June as director of the National Gallery of Art, died on April 20 at the age of eighty-six years.

AT the meeting of the American Philosophical Society held in Philadelphia on April 21, the following members were elected. *Members resident of the United States:* Donald H. Andrews, Baltimore; William Bell Dinsmoor, New York; Edward Vermilye Huntington, Cambridge; B. E. Livingston, Baltimore; Edward Martin, Media; Marshall S. Morgan, Philadelphia; G. Kingsley Noble, New York; Francis Randolph Packard, Philadelphia; Samuel Price Wetherill, Jr., Haverford; Westel Woodbury Willoughby, Baltimore, and James Thomas Young, Philadelphia. *Foreign residents,* James Colquhoun Irvine, St. Andrews, Scotland, and Max Planck, Berlin, Germany.

AT the recent charter day exercises of the University of California, the doctorate of laws was conferred on Dr. William E. Ritter, emeritus professor of zoology at the university, emeritus director of the Scripps Institution of Oceanography and honorary president of Science Service.

THE honorary degree of LL.D. was conferred at the graduation ceremony on March 29 of the University of Aberdeen on Dr. D'Arcy Wentworth Thompson, professor of natural history at the University of St. Andrews, "in recognition of the fact that he had played a leading part in guiding the scientific investigation of an industry of immense importance to the city of Aberdeen, since the time when, in 1897, as a British delegate, he had attended the Behring Seas Fisheries Conference."

THE University of St. Andrews will confer on June 30 the honorary doctorate of laws on Professor Carl Neuberg, director of the Kaiser Wilhelm Institute for Biochemistry, Berlin, and editor of the *Biochemische Zeitschrift,* and on R. S. Pearson, director of the Forest Products Research Laboratory, Princes Risborough.

ROYAL MEDALS of the Royal Geographical Society have been awarded as follows: The Founder's Medal

to Mr. J. M. Wordie, for the work he has done in polar exploration from the voyage of the *Endurance* in the Weddell Sea in 1914–17 to the present day, and the Patron's Medal to Professor Erich von Drygalski, for his researches in glaciology, both in the Arctic and the Antarctic regions. The Murchison Grant has been awarded to Dr. Noël Humphreys, for his expeditions in Ruwenzori; the Back Grant to Miss Freya Stark, for her journeys in Luristan; the Cuthbert Peek Grant to Dr. L. S. B. Leakey, for his studies on climatic changes in East Africa; and the Gill Memorial to Khan Sahib Afraz Gul Khan, Survey of India, for his frontier and trans-frontier explorations and surveys.

DR. WILHELM HIS, professor of internal medicine at Berlin, has been awarded the silver Carl Ludwig Medal for 1933, which is given every year for outstanding services in research on the circulation.

DR. ROSCOE W. THATCHER, who resigned as president of the Massachusetts State College on account of ill health in September, 1932, and has since been on leave of absence in Florida, expects shortly to return to the college where he has been appointed to a research professorship.

DR. CARL EINAR HILLE, associate professor of mathematics at Princeton University, has been appointed professor of mathematics at Yale University. Dr. Hille is a fellow of the American Academy of Arts and Sciences and managing editor of the *Annals of Mathematics*.

AT Harvard University, Dr. William Caspar Graustein has been promoted to a professorship and Dr. Marshall Harvey Stone, of Yale University, has been appointed associate professor of mathematics and tutor in the division. Dr. George Bogdan Kistiakowsky has been promoted to an associate professorship of chemistry, and Dr. Bartholomeus Jan Bok, Willson teaching fellow, has been made assistant professor and tutor in the division of the physical sciences.

DR. LAWRENCE R. BLINKS, of the Rockefeller Institute for Medical Research, has been appointed associate professor of plant physiology in the department of botany of Stanford University.

DR. HERVEY W. SHIMER, professor of paleontology at the Massachusetts Institute of Technology, has been made acting head of the department of geology to succeed Dr. Waldemar Lindgren, whose retirement was recently announced.

THE nomination of Commander R. S. Patton as head of the U. S. Coast and Geodetic Survey has been sent to the Senate by President Roosevelt. Commander Patton has been connected with the survey since 1904 and became director under the Hoover administration in 1929.

ACCORDING to an Associated Press dispatch Professor James Franck, who, jointly with Gustav Hertz, was awarded the Nobel Prize in physics in 1925, presented his resignation from the University of Göttingen to the German Ministry of Education on April 18. He is reported to have said: "I have requested my superior authorities to release me from office but will endeavor to continue scientific work in Germany."

A WIRELESS dispatch to *The New York Times* reports that the supervising board of the German Bureau of Standards, of which Professor Albert Einstein long has been a member, has expelled him on the ground that the "attitude he has taken toward the national renaissance of Germany has made his remaining a member impossible."

AN Associated Press dispatch from Berlin dated April 21 states that the German Government has appointed Gottfried Feder as president of the Reich's Technical Society, giving him control of the eighty professional scientific organizations which it represents.

DR. VERN O. KNUDSEN, associate professor of physics at the University of California at Los Angeles, has been nominated for president of the Acoustical Society of America. The annual meeting of the society will be held in Washington on May 1 and 2.

THE following officers of the Society for Experimental Biology and Medicine have been elected for the ensuing year: *President,* A. R. Dochez; *Vice-president,* E. L. Opie; *Secretary-treasurer,* A. J. Goldforb; *Additional Councilors,* C. R. Stockard and G. B. Wallace; *Nominating Committee,* F. R. Sabin, *chairman,* T. Addis, W. R. Bloor, R. Chambers, W. T. Longcope, D. Marine, A. N. Richards, C. R. Stockard, C. J. Wiggers.

OFFICERS of the American Society of Biological Chemists for 1933–34 have been elected as follows: *President,* William M. Clark, the Johns Hopkins University; *Vice-president,* Howard B. Lewis, the University of Michigan; *Secretary,* Henry A. Mattill, the State University of Iowa; *Treasurer,* Cyrus H. Fiske, Harvard Medical School; *Councilors,* Harold C. Bradley, University of Wisconsin; Paul E. Howe, U. S. Department of Agriculture; William C. Rose, University of Illinois.

DR. A. O. RANKINE, professor of physics at the Imperial College of Science and Technology, was elected president of the Physical Society, London, at the annual meeting on March 17. Dr. William Wilson,

Hildred Carlile professor of physics in the University of London, was elected vice-president.

AT the recent annual meeting of the Geological Society of London, Sir Thomas Holland was elected president and Professor E. J. Garwood, J. F. N. Green, W. Campbell Smith and Professor W. W. Watts were elected vice-presidents.

RECENT awards from the Elizabeth Thompson Science Fund have been made to Dr. S. W. Britton, University of Virginia, $150 additional, to be used for the purchase of chemicals and other supplies necessary in his study of the function of the adrenal glands, and to Dr. Erwin Chargaff, Hygienische Institut, University of Berlin, $100, for aid in his investigations dealing with the chemistry of pathogenic bacteria, especially with the lipoids and carbohydrates of the acid-fast group. The trustees of the Elizabeth Thompson Science Fund meet ordinarily during the last ten days of the months of February, May and November. Applications for grants should be sent well in advance of the meeting to the secretary of the fund, Dr. Alfred C. Redfield, the Biological Institute, Divinity Avenue, Cambridge, Massachusetts.

EIGHTEEN fellowships in medicine, including two renewals, for study in the United States and Europe during 1933–1934, were awarded at the spring meeting of the Medical Fellowship Board of the National Research Council, Washington, D. C., of which Dr. G. Carl Huber, dean of the Graduate School, University of Michigan, is the chairman. A list of the successful candidates follows: Caroline C. Bedell, Maurice Brodie, James K. W. Ferguson, Earl W. Flosdorf, Louis S. Goodman, William G. Gordon, Arthur T. Hertig, Joseph Hughes (renewal), Thomas H. Jukes, James M. Orten, Alwin M. Pappenheimer, Wesley T. Pommerenke, Clarence F. Schmidt, Jr. (renewal), Henry G. Schwartz, Randall L. Thompson, William McC. Tuttle, Arthur J. Vorwald and Samuel J. Weinberg. The 1933 fall meeting of the board will be held in September and applications to be considered at that time should be filed with the Washington office of the Medical Fellowship Board on or before August 1.

AN award of the Charles A. Coffin Foundation was recently made to Dr. Sanford A. Moss, of the General Electric Company, not Dr. Charles A. Moss, as recently reported in SCIENCE.

PROFESSOR RAYMOND L. WILDER, of the department of mathematics of the University of Michigan, has leave of absence during the next academic year to enable him to continue his special work for a year at the Institute for Advanced Study at Princeton.

DR. LEROY ABRAMS, professor of botany and director of the Dudley Herbarium at Stanford University, sailed recently from San Francisco. He expects to study during the summer in London, Paris and Geneva.

LEAVE of absence for the next academic year has been granted by Princeton University to Professor Howard Crosby Warren, of the department of psychology, and to Professor Warner Fite, of the department of philosophy, and for the first term to Professor Raymond S. Dugan, of the department of astronomy.

THE Edgar Fahs Smith Memorial Lecture will be delivered at the University of Pennsylvania on the evening of May 8 at 8:15, by Dr. James B. Conant, professor of chemistry at Harvard University. The title of his lecture will be "A Study of Extremely Weak Acids and Bases."

THE Faraday Lecture of the Chemical Society was delivered at the Royal Institution on March 29 by Professor Peter Debye, of the University of Leipzig. He took as his subject "The Relations between Stereochemistry and Physics."

PROFESSOR H. E. ARMSTRONG will deliver the Huxley Memorial Lecture at the Imperial College of Science and Technology, South Kensington, on May 4. His subject will be "Our Need to Honor Huxley's Will."

ON the occasion of the visit of Professor N. Bohr, of Copenhagen, to Pasadena for two weeks beginning on May 15, the staff of the Norman Bridge Laboratory of Physics of the California Institute of Technology plans to conduct a symposium on the general subject of the physics of nuclei and high energy transformations. Professor Bohr will deliver four lectures on the foundations of atomic mechanics, and Professor E. O. Lawrence, of the University of California, will speak on the artificial disintegration of nuclei. Other phases of recent work in this field will be discussed by various members of the staff, including Professor P. S. Epstein, Professor C. C. Lauritsen, Professor J. R. Oppenheimer, Dr. C. D. Anderson, Dr. H. V. Neher and Dr. R. M. Langer. It is planned to have lectures at 4:30 P. M. five days weekly. Professor Bohr probably will speak on Wednesdays and Fridays. A cordial invitation is extended to all who may be interested to attend and to take part in the discussions.

THE North Dakota Chapter of Sigma Xi, University of North Dakota, on March 30, had as their guest speaker Dr. G. W. Stewart, of the University of Iowa. He delivered three addresses. In the forenoon his convocation topic was "Ordinary Made Extraordi-

nary"; at the noon luncheon he made a plea for better teaching of college subjects, and at the dinner meeting, he discussed what civilization may expect from science in the future.

THE New England Association of Chemistry Teachers and the Eastern Association of Physics Teachers held a joint meeting on April 8 in the new Thompson Science Building of the Phillips Exeter Academy, Exeter, New Hampshire. This new building, the gift of the late Colonel William Boyce Thompson, of Yonkers, New York, and a graduate of the academy in the class of 1890, embodies the latest equipment and facilities for teaching chemistry and physics.

THE sixth annual scientific meeting, and twenty-seventh annual South African Medical Congress, will be held in Capetown from September 25 to 30, under the presidency of Mr. E. Barnard Fuller. The work of the congress will be divided among five sections as follows: medicine, surgery, gynecology and obstetrics, public health and special subjects (six subsections). At the three plenary sessions the topics for general discussion are: diet in relation to health in South Africa; prevention of maternal mortality in urban and rural areas in South Africa, and medico-legal problems of general practise. An exhibition of specimens of medical interest from a historical point of view is being arranged in conjunction with the trades exhibition.

DISCUSSION

THE HIGH COST OF GERMAN MEDICAL AND SCIENTIFIC PERIODICALS

THE financial problem of literature in the scientific fields, especially those of medicine and the biological sciences, has for some time been a matter of concern to those interested in educational institutions and in providing facilities for investigators engaged in scientific work. Fortunately, in most countries this type of literature has not been extensively commercialized. Wise editorial policies and economical management have prevented prices from becoming exorbitant. This has not, however, been equally true of all countries, notably Germany. Much of the German scientific literature appears in periodicals which, while containing excellent work, are since the war published at absolutely prohibitive prices. The high prices of German periodicals have affected all scientific libraries, and especially medical libraries, since the increase in prices has been the largest in the field of medicine, biology and chemistry. The Medical Library Association has been concerned for some time over this situation, which has been growing progressively worse until the subscription rates for some of these journals have now reached $90.00 to $173.00 a year.

Several interesting articles on this subject have appeared. Dr. Raymond Pearl,[1] of Johns Hopkins University, Mr. Charles H. Brown,[2] of Iowa State College Library, Colonel Fielding H. Garrison,[3] of the Welch Medical Library, Mr. Alfred L. Robert and Mr. Hans Schaltenbrand,[4] of the College of Physicians and Surgeons in New York, Dr. Wilfrid Bonser,[5] Librarian of the University of Birmingham, England, and others[6] have made excellent studies regarding the cost of scientific periodicals, and the dangers inherent in some of the present policies.

The Medical Library Association appointed a committee, consisting of Colonel Fielding H. Garrison, Mr. Alfred L. Robert and Mrs. Eileen R. Cunningham, to investigate the high cost of German medical periodicals, and see what might be done to alleviate this situation. This study has brought out several interesting facts. It is evident that in a large or medium-sized medical library in this country, two thirds or even more of the total annual appropriation for current periodicals is expended on German periodicals, issued chiefly by one or two firms, leaving less than one third of the funds available to be used for the scientific output of all other nations, including the United States and many of the more reasonably priced German publications. This is obviously an absurd situation. Appeals to these German publishers have been met with promises to reduce the volume output, but so far prices have increased and nothing constructive has been accomplished.

The fact that German scientific publications do not usually receive financial aid from foundations and scientific societies undoubtedly renders it more difficult for publication cost to be as low as in other countries, but there seems to be no justification for prices which vary from five to eight, or more, times as much as those of any other nation. It seems difficult to explain these publishers' prices on a cost plus basis. No definite yearly subscription price is announced;

[1] Raymond Pearl, "Cost of Biological Books in 1928." *Quarterly Review of Biology*, 3: 600–603, 1928.

[2] Charles H. Brown, "A Hazard to Research," *Journal of Higher Education*, 2: 420–426, 1931.

[3] Fielding H. Garrison, "Dangers Besetting the Literature of Recent Medicine." Festschrift zur Feier des 60. Geburtstages Max Neuburger, Wien, 1928. "The High Cost of Current Medical Periodicals." *Bulletin of the Medical Library Association*, n. s., 20: 165–169, 1932.

[4] Alfred L. Robert and Hans Schaltenbrand, "The Comparative Cost of Medical Journals." *Bulletin of the Medical Library Association*, 20: 140–155, 1932.

[5] Wilfrid Bonser, "The Cost of German Biological Publications." *Library Association Record*, n. s. 6: 252–256, 1928.

[6] "The Cost of German Medical Journals." Editorial, *Canadian Medical Association Journal*, 27: 63–64, 1932.

one number of a journal may cost $5, while the next may cost $10, and yet only perhaps thirty to forty more pages are included, and the plates, curves and charts do not seem essentially different from those of the less expensive number.

We are also convinced that if the editors and publishers of these expensive journals would really cooperate in an earnest effort to bring down prices, something could be accomplished. The chief responsibility rests with the publishers, however, for in Germany they control the medical publications, employ the editors and pay for the papers printed in the journals. Lately, in every commercial undertaking, prices have been scaled to meet changed economic conditions, and the publishing business should be no exception to this rule.

These German publishers have cautioned libraries against cancellation, as they say that a decrease in the number of subscriptions would lead to an increase of prices for the remaining subscribers. Many American libraries are facing reduction of income, and every means possible is being considered whereby economies can be effected. Therefore, it is obviously impossible for many of them to continue subscriptions to these high priced journals. Many European libraries and individual subscribers, even in Germany, have been forced to cancel their subscriptions, and unless there is evidence of a change in policy on the part of the German publishers, it will not be long before there will be wide-spread cancellation of these high-priced journals by American libraries, who are at present among the most extensive subscribers. If this is to be met by further increase in prices, still further cancellations will result, and a vicious cycle established which would certainly be unfortunate for all concerned.

The Medical Library Association therefore decided to issue an appeal to the German scientific and medical societies and to editors of German medical journals. The American College of Physicians joined the Medical Library Association in this appeal, which was issued in January 1933.[7] This letter summarized the situation and urged German scientists to use their influence and cooperation wherever possible to bring about a decrease in the cost of these journals before wide-spread cancellation had become inevitable.

A few suggestions were made as to possibilities in accomplishing this objective: (1) Decrease in the size and number of the volumes, through briefer articles and careful editorial selection; (2) fixed annual subscription prices for the journals; (3) statements in advance of the approximate number of volumes to appear each year.

That the present situation is considered unfortunate by many Germans is indicated by several articles which have appeared lately in the German journals,[8,9] showing that the subject is being given consideration there as well as elsewhere.

The situation is a serious one, and those interested in medical education, scientists and investigators, especially in the fields of medicine and the biological sciences, should use any influence they may have with German colleagues to urge their cooperation in reducing the prices of these scientific journals. It is also of the utmost importance for such individuals to study the situation in regard to the particular library from which their reference material is drawn.

In view of present economic conditions, it is likely that the next few years will see the cancellation of large numbers of these expensive German journals, until they will be available only in the large cities, and in libraries with large endowments. This means that investigators working at a distance from such centers will be at a disadvantage as compared with other colleagues; but unless within the next few months marked cooperation is shown on the part of the editors and publishers of these high-priced German journals, the unfortunate results outlined above will inevitably take place.

That we, in this country, can continue indefinitely to expend 70 per cent. of our current periodical budgets for perhaps forty or fifty journals published by a few German firms is extremely unlikely; especially when there are three to five hundred journals necessary for a good medical library, many of which certainly contain material as valuable as that appearing in the journals which are so excessively high priced.

EILEEN R. CUNNINGHAM,
Chairman, Committee on Cost of Current Medical Periodicals, Medical Library Association
VANDERBILT UNIVERSITY
SCHOOL OF MEDICINE

[7] This letter was published in full in the *Bulletin of the Medical Library Association*, n. s., 21: 90–91, 1933. Reprints can be obtained by those interested on application to the Chairman of the Committee on Cost of Current Medical Periodicals.

IS LONGEVITY COMPATIBLE WITH OPTIMUM GROWTH?

MODERN nutrition is governed by the philosophy that a diet which produces optimum growth in the young animal is the ideal. This carries with it the assumption that optimum growth means optimum health. When experimental findings are applied to

[8] Georg Leyh, Address delivered before the Vereins Deutscher Bibliothekare und des Verbandes Deutscher Volksbibliothekare in Jena am 18. u. 19. Mai 1932. *Zentralblatt für Bibliothekswesen* 49, Heft 8, 1932.

[9] H. Morstatt, "Über die Notwendigkeit, den Umfang der wissenschaftlichen Veröffentlichungen einzuschränken." *Die Naturwissenschaften*, 19: 968, 1931.

man, they usually imply the additional assumption that optimum growth leads also to long duration of life, commonly termed longevity. There is no doubt that the nutrition of animals that are to be slaughtered for meat shortly after they mature should be considered from the point of view of rapid growth, since that implies efficient feed conversion. On the other hand at the present time it is the general practise of those who are concerned with child nutrition to attempt to attain the maximum growth of the child without regard to the possible interrelationship between such growth and a short life span. The same philosophy dominates the practises of rearing dairy calves and horses to maturity as rapidly as possible although it is desirable that they have a long productive life span.

In 1912 Slonaker[1] reared three male rats upon an omnivorous diet. Their mean length of life was 1,222 days, but it required 391 days for these rats to attain their maximum weight. A study of Slonaker's growth data indicates that these rats really grew very slowly to maturity and that they did not grow rapidly and then merely fatten to a maximum weight as middle age approached. I have disregarded Slonaker's data upon exercised rats, because there is nothing in the literature for comparison. I have not cited his data upon the vegetarian groups because they died relatively young and need not be considered in a discussion of longevity.

In a report concerning the rat diet that has proved satisfactory as far as reproduction and growth in our colony is concerned, Maynard[2] showed most of the growth of the male rat takes place before the sixteenth week with a gradual weight increase until the twenty-eighth week. During the past four years we fed a group of seventy-five male rats upon this diet until they died. Their mean age at death was 503 ± 12 days. Only 1 of these rats lived for more than 900 days.

Although Slonaker's data are very limited they indicate that our rats upon the stock diet are dying in middle age. Our rats matured rapidly, those of Slonaker slowly.

In our studies upon brook trout we have reported experiments twice in which trout that failed to grow lived much longer than those that grew upon similar diets.[3, 4] This first called our attention to the possible relationship between the rate of growth and the span of life within a given species. A relationship between rate of attaining maturity and life span between various species is frequently mentioned by early biologists, however Zabinski[5] from his studies with insects has noted the possibility of prolonging life by retarding the growth rate. Osborne and Mendel[6] suggested the same possibility from their studies with rats.

Miss Campbell[7] found she could extend the mean length of life as well as the growth of rats slightly by increasing the milk in the diet. In the light of Slonaker's data, these findings have only negative bearing upon the problem of longevity because even her group that lived the longer died in approximately middle life at a mean age of 664 days. All her many hundreds of rats died without any attaining the mean age of Slonaker's three males and her value for mean age disregards early deaths. Therefore her data indicate nothing concerning the interrelationship of growth and longevity. Her findings also confirm those of others that the female rat grows more slowly and outlives the male.

We may then have diets that are entirely satisfactory for growth and reproduction and these same diets may be unsatisfactory for longevity. It is known from many experiments that we may have a slow growth rate and a short life span upon a deficient diet. No one has ever found it possible, however, to have both rapid growth with early attainment of maturity, and longevity. It is possible that longevity and rapid growth are incompatible and that the best chance for an abnormally long life span belongs to the animal that has grown slowly and attained a late maturity.

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[4] C. M. McCay, *et al.*, *Trans. Am. Fish. Soc.*, 61: 58. 1931.
[5] J. Zabinski, *Jour. Exp. Biol.*, vi: 360. 1929.
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SOLUBLE SESQUIOXIDES AND ORGANIC MATTER FROM ALKALI TREATMENTS ON SOILS

ALKALI treatments, equivalent to one ton per acre, on Appalachian upland podzol soils of Quebec have been studied in percolators in an attempt to break down the relatively large amount of organic matter and to decrease the acidity (pH about 5.0, "lime requirement" 3 tons CaO per acre). The results found differ from those reported by Meyer[1] based on the effects of calcium carbonate applied to Caddo silt loam of pH 4.8. Liming podzol soils has not produced the large increases in soluble iron and organic matter found in the case of the acid Louisiana soils. On the other hand, equivalent treatments with sodium hydroxide and sodium carbonate on these podzol soils give marked increase of soluble organic matter in

[1] A. H. Meyer, "Iron Toxicity from Liming," SCIENCE, 76: 56. 1932.

colloidal suspension in the soil solution. In addition, iron and aluminum are found adsorbed by this organic material to the extent of about 40 p.p.m. and 20 p.p.m. of the soil, respectively. These soils and soil solutions with this treatment remain acid between values of pH 6.1 and 6.7.

Iron toxicity, due to increase in soluble iron after liming, has been claimed for the Louisiana soils, but the evidence that we possess indicates that the presence of the soluble sesquioxides in small amounts after sodium alkali treatment does not inhibit production from these Quebec soils but permits positive increases.

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THE ATTRACTION OF SPHERES

IT is appropriate that some warning should be given the inexperienced reader of Mr. Thaddeus Merriman's article in SCIENCE for April 14 (p. 371). His method of calculating the attraction of a homogeneous sphere upon a neighboring body involves assumptions inconsistent with the generally accepted methods of the integral calculus, as well as with the Newtonian law of gravitation. Newton's beautiful geometrical proof that the net attraction of such a sphere is exactly the same as if all the mass was concentrated at its center is, of course, fully confirmed by the rigorous analytical discussion which may be found in any standard treatise on mechanics, and so need not be reproduced here.

Mr. Merriman's proposed substitute law is inconsistent not only with theory but with the fact. For a small sphere near the earth's surface, it reduces to $F = G \frac{M, \cos \alpha}{d^2}$, when M is the earth's mass, d its radius, and α the angle between a line drawn to the earth's center and one tangent to a circle of radius 0.424 times the earth's. The factor $\cos \alpha$, which is omitted in Newton's equation, has the value 0.911 for a point on the earth's surface. Without it the attraction at the surface is known to be in complete agreement with that inferred from the orbital motion of the moon. To introduce it destroys the agreement, which provided Newton with the first conclusive test of his theory.

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PRINCETON
APRIL 21, 1933

SCIENTIFIC APPARATUS AND LABORATORY METHODS

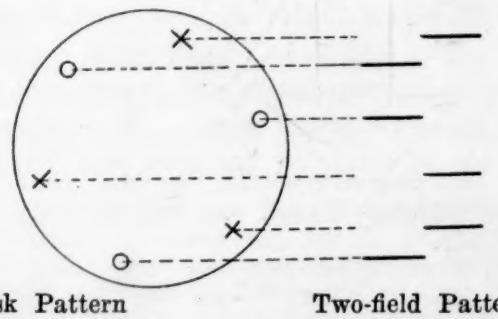
A TWO-FIELD STROBOSCOPE

IN stroboscopic observation of vibrating strings for measurement of frequency, no use seems to have been made of a two-field illumination. The two fields are contiguous and are alternately illuminated. The two-field method removes some ambiguities of the one-field method. But more important is the fact that a feeble resonance of the string to a tuning-fork or other source is more easily detected.

For the laboratory, the simplest device is the type of Neon bulb built for a. c. lighting circuits and having semi-cylindrical electrodes. Such a bulb can be held behind a string in such a manner that half of each electrode is visible. The two electrodes light up in alternation, the flash frequency of either side being equal to the frequency of the current.

For lecture demonstration, one can take a siren disk with an even number of holes. Alternate holes are half covered on the half nearest the center of the disk; the remaining holes are half covered on the side next the edge of the disk. The disk is set as closely as possible to the string, with the center of the disk level with the string. When a hole is level with the string, a strong beam of light is made convergent by means of a condenser, and is arranged to just cover either type of hole. On the other side, an objective focusses the string on a screen. When the disk is rotated and the string made to vibrate, a two-field stroboscopic view of the string is obtained. (Many other methods may be used.)

To understand the patterns seen, the procedure is to construct in advance the patterns to be expected. To do this, imagine a stroboscope disk with a single spot; rotate this at S revolutions per second, S being the string frequency; and illuminate the disk by F flashes per second. When the pattern has been worked out, project the spots of the pattern on a vertical line in the plane of the disk. Then repeat the process for a series of flashes beginning one half flash-period later. The projections of this second pattern gives the string pattern in the other field. The figure herewith illustrates the case when the flash frequency is 3/5 of the string frequency. Small circles give the first disk pattern, and crosses give the second.



Disk Pattern Two-field Pattern

Figure illustrating the construction of the two-field pattern for F = S.3/5.

A few simple rules may be given here. Assume that F = S.f/s.

For the disk patterns:

(1) Sf/s flashes per second produce a pattern of f spots, independently of the value of s.

(2) If s is even, the crosses coincide with the circles.

(3) If s is odd, the crosses alternate with the circles.

For the two-field string patterns:

(1) The number of lines seen in either field is equal to f; when two lines merge into one, that line must be counted twice.

(2) If s is even, the two fields are identical, and appear as a single field.

(3) If s is odd, the two fields are similar but not identical.

It is rarely the case that f/s is a simple ratio. Then, as in Lissajou curves, one sees changing patterns. These can be worked out by shifting the initial position of the disk in the construction shown above. It is just this fact that makes the two-field method so convenient. Assume that a string has been tuned to the frequency F, for which we obtain just one line in either field. If the string starts to resonate to some source, one can usually observe two lines moving in opposite directions. The writer has used a ×25 microscope to observe such resonances.

The changing patterns just mentioned can be worked out by a slow rotation of the disk patterns, as stated. From this it will be understood that a complete cycle of change means that the disk has moved by an angle equal to the angle between two spots of the same set. Or in the two-field patterns, we have made a complete cycle of changes when we return to some pattern in the same way. Then, if the pattern corresponds to a ratio f/s, and there are R complete repetitions per second,

$$\frac{F}{f} - \frac{S}{s} = \frac{\pm R}{fs}$$

Although, for simplicity, we have spoken of strings, the two-field method is adaptable in many ways to the observation of other bodies, *e.g.*, the writer used a Neon bulb in the selection of steel springs which were to vibrate at a frequency of 240.

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REGULATING THE AIR SUPPLY OF MICRO BURNERS

MOST of the micro burners obtainable from supply houses have an inflexible and very often an inefficient adjustment of the gas-air mixture. The usual practise with laboratory workers has been to test a number of burners and then select the best of the lot, without attempting adjustment. Obviously, this is an awkward and somewhat unsatisfactory solution of the problem.

A method, almost as convenient as that used for the Bunsen burner, has been found for regulating the air supply of micro burners. The small burner is connected to the gas line and lit. While the flame is burning, twist with a pair of pliers the metal gas connection which projects from the base, loosening or tightening until the proper type of flame is obtained.

Occasionally a burner will be found which requires further treatment. In these cases the gas connection is unscrewed and, using a small three-cornered file, two flat channels about 5 mm wide and 6 or 8 mm long are filed on each side of the tube. These shallow channels start from the middle of the tube and slant upward, meeting at the pin hole gas outlet on top. The connection is replaced frequently while filing and the gas-air mixture tested as described above, in order to prevent spoiling the burner by too much filing. If necessary, the small gas outlet can be made larger by reaming with a pin. However, it is usually found that the opening is already too large. This can be remedied by filing the sides of the hole rather thin and then pressing the edges inward until the desired opening is obtained.

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SPECIAL ARTICLES

ACCELERATED, EXPERIMENTAL POLIOMYELITIS IN NASALLY INSTILLED MONKEYS

IN a previous communication,[1] attention was directed to the accelerating effect of a second virus injection, after an interval of from 7 to 10 days, in provoking experimental poliomyelitis in *Macacus rhesus*. The earlier report dealt with the phenomenon from the point of view of establishing human strains of virus in monkeys. Since that report was made, additional studies of the subject of accelerated infection have been undertaken.

The first test, made by injecting the human virus intracerebrally and intraperitoneally, were soon followed by the injection of sub-infective doses of monkey virus intracerebrally alone. The results showed that acceleration does not depend on the

[1] S. Flexner, "Accelerated Infection in Experimental Poliomyelitis," SCIENCE, 1931: 74, 520.

presence of foreign (human) nervous tissues along with the virus, and probably is not simply a summation effect of the two virus injections.

The events following the second or accelerating injection of virus are characterized by an abrupt rise in temperature (105° to 106°+ F.) and the onset of paralysis, often rapid, which may progress quickly to prostration and death. The accelerating action has now been shown to apply also to monkeys receiving the virus by instillation into the nasal cavities. Since the natural infection in man takes place through these cavities, this observation may prove to have practical import. The virus, in suspension, is dropped into the nares on two successive days; and if infection does not manifest itself in from 7 to 10 days, the instillations are repeated. After one or two such instillations, symptoms, consisting of fever and paralysis, may manifest themselves promptly, as in the instances of intracerebral inoculation.

The sudden onset of severe symptoms following the second nasal instillations has suggested not only relationship with the phenomenon in children described by Draper[2] under the term "dromedary" type of poliomyelitis, but has also supplied a possible explanation of its nature. According to this provisional explanation, the "dromedary" effect is a result of reinfection, arising either from the patient himself (autochthonous infection) or from a new exposure to the virus.

The path of the virus introduced into the nares—ascending by way of olfactory nerve cells in the mucous membrane to the olfactory lobes of the brain, and then to other parts of the nervous system in regular sequence—has become more firmly established as the experimental study of poliomyelitis has progressed.[3] The part taken by the meningeal choroid plexus complex in the extension of the virus has been little studied.[4] Upon examining, on successive days, the cerebrospinal fluid withdrawn by lumbar puncture after the first and second sets of nasal instillations of virus, it was found that the number of mononuclear cells in the fluid increases considerably, even before the appearance of any symptoms of infection, except sometimes fever (105° F.), and that the occurrence of fever, increased cells and the presence of globulin in the fluid may be the only detectable pathological effects of the instillations. However, the second instillations are succeeded, but not invariably, by a further rise in cells and by the appearance of paralysis, which may extend rapidly, leading to death; or the paralysis may be partial, become arrested and terminate in recovery. It remains to be determined whether monkeys which develop the cerebrospinal fluid changes only, exhibit later a heightened resistance (immunity) to the virus injected intracerebrally, and whether the blood serum has acquired antiviral properties. The occurrence of these mild effects from the instillations may profitably be compared to the alterations in the cerebrospinal fluid observed during epidemics of poliomyelitis in certain children who develop no detectable paralytic symptoms whatever.

The acceleration procedure has been employed advantageously in still other ways: (1) To determine the neutralizing action of blood sera in respect to strains of virus differing qualitatively and quantitatively from one another; and (2) to throw light on the degree and duration of active immunity in monkeys that have recovered from an acute attack of experimental poliomyelitis, or have been rendered immune by the intradermal injection of virus. In the first instance, intracerebral, and in the second, intranasal inoculation is performed. A greater degree of regularity and accuracy has been introduced into these difficult tests by the use of the acceleration method in the experimental study of poliomyelitis.

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